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Design of Road Pavement by Soil Stabilization

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Abstract: Highway engineering is an engineering discipline branching from civil engineering that involves the planning design, construction, operation and maintenance of roads, bridges to ensure safe and effective transportation of people and goods. Standards of highway engineering are being continuously improved. These days construction of pavements on expansive soils expand while wet and contract when dry. This may cause potholes and cracks on the surface of pavement and life of the pavement decreases and cost of construction increases. In order to overcome this problem different additives are used to stabilize the soil. In this project crushed bituminous aggregate is used to stabilize the soil different percentages of crushed bituminous aggregate and fly ash is added to soil sample and CBR values are found. Using CBR values pavement thickness is found for each percentage of crushed bituminous aggregate.
Keywords: Crushed Bituminous Aggregate, California Bearing Ratio, fly ash, flexible pavement.

I. INTRODUCTION

Generally during construction of roads we may face many problems due to poor soil sub-grade. Cohesive soils can creep over time under constant load, especially when the shear stress is approaching its shear strength, making them prone to sliding. Especially in case of clayey soils the problems may be high because of its low shear strength. They are plastic and compressible and they expand when it is wet and shrink when it is dry. This is an undesirable feature and these types of soils are generally poor for foundations. In case of pavements it causes ruts and potholes on surface of pavement. The presence of potholes may cause problems to the vehicles moving on the road. To overcome the problem civil engineers started stabilizing soil in order to construct pavements on any types of soil. Soil stabilization not only decreases structural failures of roads but also it helps in reducing pavement thickness, which reduces the cost of construction. The main objective of this project is to stabilize soil using fly- ash and crushed bituminous aggregate. Fly-ash is a by-product formed during combustion of coal. Fly-ash is very effective in stabilizing expansive soils. The engineering properties of soil are improved by adding fly-ash by 10% of soil weight. In addition to fly-ash, bituminous aggregate is added to improve the properties of soil. It increases load bearing capacity of soil and helps in decreasing pavement thickness. Most of the Indian highways system consists of flexible pavement; there are different methods of design of flexible pavement. The California Bearing Ratio (CBR) test is an empirical method of design of flexible pavement design. It is a load test applied to the surface and used in soil investigations as an aid to the design of pavements. The design for new construction should be based on the strength of the samples prepared at optimum moisture content (OMC) corresponding to the Proctor Compaction and soaked in water for a period of four days before testing. In case of existing road requiring strengthening, the soil should be molded at the field moisture content and soaked for four days before testing. It has been reported that, soaking for four days may be very severe and may be discarded in some cases. This test method is used to evaluate the potential strength of subgrade, sub-base and base course material for use in road and airfield pavements. The design of the pavement layers to be laid over subgrade soil starts off with the estimation of subgrade strength and the volume of traffic to be carried. The Indian Road Congress (IRC) encodes the exact design strategies of the pavement layers based upon the subgrade strength which is most commonly expressed in terms of the California Bearing Ratio (CBR). For the design of pavement CBR value is invariably considered as one of the important parameter. With the CBR value of the soil known, the appropriate thickness of construction required above the soil for different traffic conditions is determined using the design charts, proposed by IRC. CBR value can be measured directly in the laboratory test in accordance with IS: 2720 (Part-XVI) on soil sample procured from the work site. Laboratory test takes at least 4 days to measure the CBR value for each soil sample under soaked condition. In addition, the test requires large quantity of the soil sample and the test requires skill and experience without which the results may be inaccurate and misleading.

II. EXPERIMENTAL PROGRAM

For checking the properties of the soil, reported different properties like Grain Size Analysis, maximum dry density (MDD), optimum moisture content (OMC), liquid limit (LL), plastic limit (PL), plasticity index (PI), etc.

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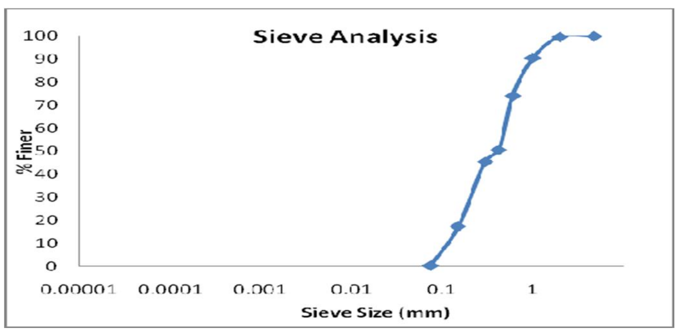
III. MATERIALS AND METHODOLOGY

Loose red earth was obtained from Mira Road, soil Sample were collected at a depth of 1 meter, soil passing 4.75 mm sieve is used in tests, all tests are conducted based on IS: 1498 – 1970 and The material which is collected for testing is different in quality and property, so that the material was separately tested in the laboratory so as to design the soil sub grade.

A. Sieve Analysis

IS Sieve Size (mm)	Weight Retained (gm)	Percentage Weight Retained (gm)	Cumulative Percentage Retained (%)	Cumulative Percentage finer (%)
4.75	-	0	0	100
2	2.61	2.61	0.37	99.63
1	64.3	66.91	9.5	90.5
600	116.2	183.37	26.12	73.88
425	163.2	346.57	49.37	50.63
300	36.24	382.81	54.53	45.47
150	197.66	580.47	82.69	17.31
75	119.28	699.75	99.68	0.32
Pan	2.2	701.95	100	0

Table No 1: Sieve Analysis of Soil



Graph 1: Sieve analysis Test curve

B. Summary of Results

Percentage of Gravel in soil sample = Nil

Hydrometer Analysis (IS 2720 – Part 4)

Purpose

Hydrometer analysis is used to find percentage of various soil grains finer than 0.075mm

Elapsed Time, t min	Actual Hydrometer reading, R_h	Corrected hydrometer reading, $R_{cl}=R_h+C_m$	H	He	Particle size, D(mm)	Perce ntage of fineness
30	1.014	14.0	5.5	12.19	6.37x10-3	43.55
1	1.012	12.0	6	12.69	4.59x10-3	37.33
2	1.0115	11.5	6.2	12.89	3.27x10-3	35.7
4	1.0095	9.5	6.5	13.19	2.34x10-3	29.55
8	1.007	7.0	7.2	13.89	1.70x10-3	21.77
16	1.005	5.0	7.6	14.29	1.22x10-3	15.55
30	1.0045	4.5	7.7	14.39	0.89x10-3	14
50	1.0025	2.5	8.2	14.89	0.70x10-3	7.7

Table No 2: Hydrometer analysis

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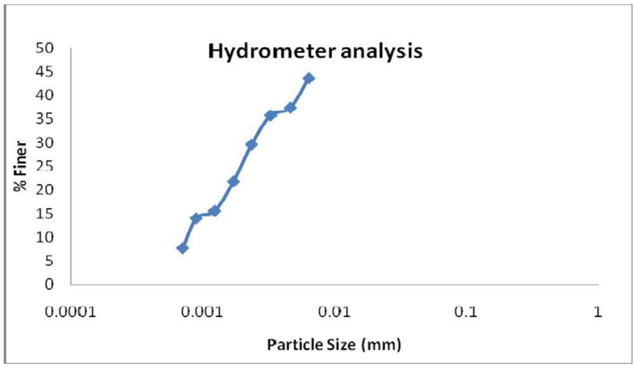
Graph 2: Hydrometer analysis



Percentage of soils is 23% and Percentage of clay is 77%.

C. Determination of Liquid Limit (LL) Using cone Penetration Method

Liquid limit is the water content at which the soil changes from liquid state to plastic state. In other words, liquid limit is the water content at which the soil passes from zero strength to infinitesimal strength.
Liquid Limit (LL) = 22%

D. Determination of Plastic Limit (PL)

Table 3: Determination of Plastic Limit (PL)

Sr.No.	Determination No.	1	2	3
1	Container Number	17	22	34
2	Weight of container + wet soil (gm)	20.10	17.02	19.2
3	Weight of container + dry soil (gm)	0.13	0.08	0.03
5	Wt. of container (gm)	20.23	17.10	19.23
6	Wt. of dry soil (gm)	0.68	0.39	0.26
7	Moisture content %	19.1	20.5	11.53

Plastic Limit (PL) = 17.04 % Plasticity Index (Pl) = LL - PL = 3.95

E. Standard Proctor Test (IS: 2720 - Part 7)

1) Calculation

a) Description of Sample = Well Graded Sand
b) Weight of Mould = 4250 gm
c) Volume of Mould = 1000 cc

Sr. No	Determination No.	1	2	3	4
1	Weight of Mould + Compacted soil (kgs)	2.922	3.00	3.034	3.05
2	Weight of container + wet Soil (gm)	46.34	44.80	50.21	50.99
3	Weight of container + Dry soil (gm)	40.46	39.85	46.41	45.79
4	Water content (%)	5.12	9.08	14.69	18.65
5	Dry Density(gm/cc)	2.704	2.817	2.85	1.786

Table 4: Data Sheet for Proctor Compaction Test.

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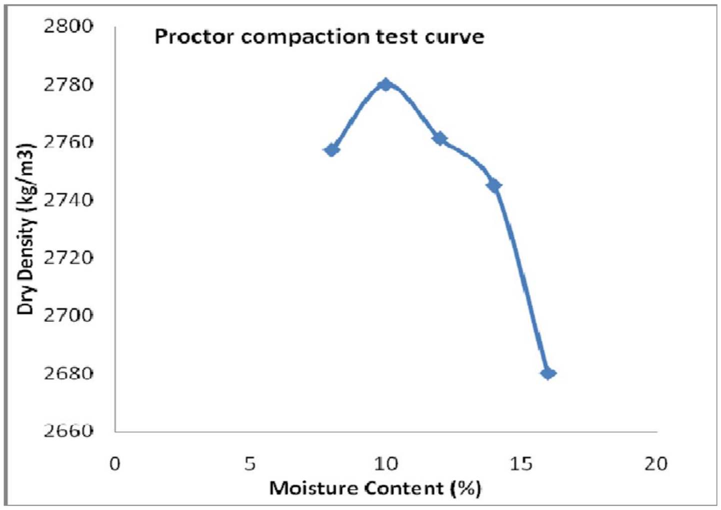
2) *Results:* (As per Graph Below)
a) Optimum moisture content = 10%
b) Maximum dry density = 2780 kg/m^3



The California Bearing Ratio Test (IS: 2720 - Part 16)

3) *Calculation*
a) Sample = Well Graded Sand.
b) Source of material = Mira Road

IV. RESULTS

A. *Only Soil*

2.5 mm Penetration CBR = Test load/ Standard load × 100% = (52.5/1370) × 100 = 3.9%
5 mm Penetration CBR = Test load/ Standard load × 100% = (115/2055) × 100 = 5.6%

B. *Calculation of Pavement Thicknesses*

Available Data
1) Design of CBR of Subgrade Soil: 5 %
2) Design Life of Pavement: 10 years
3) Annual Growth rate: 5 %
4) Distribution of Commercial vehicle for Single Lane: Single Lane
5) Computation of Design traffic for the end of Design life: 0.75

C. *Computation of Design Traffic*

The design traffic in terms of the cumulative number of standard axles to be carried during the design life of the road should be computed using the following equation:
N = {365×[(1+r)^n-1]/r}×{A×D×F) }
N = The cumulative no. of standard axles to be catered for in the design in terms of msa.
A = Initial Traffic in the year of completion of completion of Construction in terms of the number of Commercial Vehicle Per Day (CVPD)
1) *Case-II* Soil + 10 % Fly ash+5% Bituminous aggregate
Total pavement thickness = 645 mm
Pavement composition interpolated as per MORT&H (IRC37- 2012 plate 4)
2.5 mm Penetration CBR = Test load/ Standard load × 100% = (54/1370) × 100 = 3.94%
5 mm Penetration CBR = Test load/ Standard load × 100% = (139.74/2055) × 100 = 6.8%

D. CBR Value for subgrade soil = 5.6%

1) CBR Value for subgrade soil + 10% Fly ash +5% bituminous aggregate =6.8%
2) CBR Value for subgrade soil + 10% Fly ash+10% bituminous aggregate=12.6%
3) CBR Value for subgrade soil + 10% Fly ash+15% bituminous aggregate =8.1%
4) CBR Value for subgrade soil + 10% Fly ash+20% bituminous aggregate=3.8%

E. Traffic Volume Count Survey

Commercial Vehicle per day = 800 nos
A = P (1+r)^x
P = No. of commercial vehicles as per last count
x = No. of years between the last count and the year of Completion of construction
D = Lane distribution factor
F =Vehicle damage factor
n = Design Life in Years
r = Annual growth rate of commercial vehicles

F. Design Calculation of Pavement Thickness

1) Commercial Vehicle at last count "P" =800CV/Day 2. r =7.5%
2) x =1
3) A =840
4) D =1
5) F =3.5
6) N = 23.15 msa (say 24 msa)

a) *Case-I* Total thickness of pavement for design CBR 5.6%

For 5% design traffic 24 msa of IRC37, 2012 Total Thickness = 697mm
Pavement composition interpolated as per MORT&H (IRC37- 2012 plate 3)

(a) Granular Sub base = 300 mm
(b) Base course = 250 mm
(c) DBM = 107 mm
(d) BC = 40 mm

Sr. No	Description	Layers	Layers Thickness
1	Soil	Granular Sub base	300
2		Base Coarse	250
		Dense Bituminous Macadam (DBM)	108
3		Bituminous Coarse	40

b) *Case-II* Soil + 10 % Fly ash+5% bituminous aggregate **-** Total pavement thickness = 645mm

Sr. No	Description	Layers	Layers Thickness
1	Soil	Granular Sub base	260
2		Base Coarse	250
		Dense Bituminous Macadam (DBM)	96
3		Bituminous Coarse	40

c) *Case-III* Soil + 10 % Fly ash+10% bituminous aggregate - Total pavement thickness = 575mm

Sr. No	Description	Layers	Layers Thickness
1	Soil	Granular Sub base	200
2		Base Coarse	250
		Dense Bituminous Macadam (DBM)	85
3		Bituminous Coarse	40

d) *Case-IV* Soil + 10 % Fly ash+15% bituminous aggregate - Total pavement thickness = 580mm

Sr. No	Description	Layers	Layers Thickness
1	Soil	Granular Subbase	200
2		Base Coarse	250
		Dense Bituminous Macadam (DBM)	91
3		Bituminous Coarse	40

e) *Case-V* Soil + 10 % Fly ash+20% bituminous aggregate - Total pavement thickness = 797mm

Sr. No	Description	Layers	Layers Thickness
1	Soil	Granular Sub base	380
2		Base Coarse	250
		Dense Bituminous Macadam (DBM)	128
3		Bituminous Coarse	40

G. Pavement Thickness Comparison

Using iron oxide CBR value of the soil increased by 6.8% and pavement Thickness has decreased by 130mm.

Sr. No	Bituminous aggregate %+10% Fly ash	Thickness of pavement in mm
1.	0%	697
2.	5%	646
3.	10%	480
4.	15%	581
5.	20%	798

V. CONCLUSIONS

Life and functioning of flexible pavement depends on sub grade soil. To improve the maintains and functioning of pavement the properties of soil sub grade is improved by adding additives like fly ash and bituminous aggregate. 10% of fly ash is added along with different percentages of bituminous aggregate and is found to be stabilized at 10% fly ash + 10% bituminous aggregate. Using bituminous aggregate CBR value of the soil increased by 6.8% and the thickness of pavement has decreased by 130mm.

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